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Case Report

Acute death due to hyperextension injury of the cervical spine caused by falling and slipping onto the face

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Abstract

This retrospective study presents findings of cases involving fatal injuries, in which the victim was found dead at the scene, resulting from cervical hyperextension force attributable to a fall from a low height. External postmortem examination of 14 victims revealed that abrasions and lacerations of the face or the forehead are typical indicators of a direct impact. Either a disruption at the disk space or a transverse fracture of the vertebral body was apparent in the spinal column. The most frequent disk disruption injury occurred at the inter-vertebral space between C4 and C5, and double disruptions were observed in four instances. The damaged cord demonstrated central hemorrhage; moreover, axonal fragmentation and neuronal chromatolysis in the white matter column were evident histopathologically. The elderly victims (mean age, 64.7 years), many of whom displayed elevated blood alcohol levels, experienced the injury consequent to a fall from a low height, a fall during bicycling or slipping on a slope under accidental circumstances.

Keywords: Hyperextension; Cervical spine; Alcohol; Elderly; Falls

1. Introduction

Extension and flexion injuries of the cervical spine, which occur during accelerated motion as in traffic accidents and falls, are characterized by a backward or a forward thrust of the head exceeding the movable range.[1] In particular, whiplash injury is typical in drivers and passengers involved in traffic accidents.[2] However, fatalities due to high energy trauma, such as motor vehicle collisions or a fall from a significant height, usually exhibit multi-system injury such as fractures of the head and the chest. The combined injuries mask the severity and mortality of the cervical injury; furthermore, enrolled forces on a body experiencing poly-injuries are complicated.[3] On the other hand, death resulting from a single force associated with cervical hyperextension is observed on occasion consequent to a fall from a low height and slippage on a slope onto the face or the forehead. Only abrasions and bruising of the face, the so-called 'facial sign', are apparent in the victims.[4] The transmitted hyperextension force gives rise to injuries of the vertebral column and the spinal cord.[5,6]

However, to the best of our knowledge, the number of reports describing autopsy findings in acute deaths related to cervical hyperextension is relatively limited.[7–11] This retrospective study documents the common features observed during postmortem gross and microscopic examinations of fatalities resulting from the single force of cervical hyperextension. The circumstances of the injuries are also presented.

2. Methods

The full autopsy record in our department was reviewed retrospectively for the seven-year period of 1999–2005. Seventy-eight deaths due to falls were selected, of which 64 were excluded because of trauma to the chest or abdomen. The force experienced by the victim during the accident was investigated in terms of external injuries and accident

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circumstances.[12] The vertebral bodies were sawn longitudinally at two opposite sides to open the spinal canal. Following removal of the spinal cords, they were fixed in 10% buffered formalin for one week. After specimens were sectioned into vertical planes in 0.4-cm intervals, paraffin-embedded tissues were prepared from each. Sections were stained with two series of Mayer's hematoxylin plus eosin and Bodian for microscopic histological evaluation. Blood alcohol level was determined with gas chromatograph via the head-space method involving nitrogen as a carrier gas; isopropanol served as the internal standard.

3. Results

3.1. Macroscopic findings

Acute deaths resulting from cervical injury were selected for evaluation in the current study. Based on the injuries and death scene investigations, 14 victims in whom a hyperextension type of force was thought to have been responsible with respect to mortality were examined. In all cases, abrasions and bruises were evident on the forehead or upper part of the face, which was the site of primary impact; lacerations were present in four victims. Abrasions were also apparent on the extremities in some instances; otherwise, no obvious injuries were apparent on their bodies.

Internal findings at autopsy revealed linear tears of the anterior longitudinal ligament in the cervical vertebra, through which mild bleeding spread into the prevertebral fascia in all cases. Twelve subjects sustained transverse clefts between one vertebra and the inter-vertebral disc space at the ligament tear; four instances of double clefts were evident (Table 1). The injured endplates of the disc exhibited complete dislocation, in which small bone fragments separated from the margin was characteristic (Fig. 1A). In two other victims, the spine injury consisted of complete transverse fracture of the vertebral body in the form of a teardrop fracture; a compressive fracture was not observed. No obvious intrusion of portions of the spinal column into the canal was observed. Although the posterior elements of the vertebrate were not extensively examined in some cases, no anterior subluxation was also observed. In the 14 cases, disk disruptions and bony fractures were distributed from the inter-vertebral space between C2 and C3 to that of C6 and C7. The lower cervical vertebrae tended to be affected; moreover, the level most frequently involved was the spine between the C4 and C5 vertebrae (Fig. 2).

One subject had a thin layer of blood in the subdural space. Others had no subdural hematoma of any measurable volume, including the brain. Prior to sectioning the spinal cords of all subjects appeared normal. However, a linear or rounded central hemorrhage was evident in the longitudinal slices in 11 cases (Fig. 1B). No subjects sustained the brainstem lacerations or other brain trauma.

3.2. Microscopic findings

Histopathological examination disclosed the presence of hemorrhage in lesions of the damaged cords; however, edematous change and macrophage invasion were not apparent, except in two cases. In particular, fragmentation of axons, which displayed coiled and bold myelin fibers,

Table 1
A list of hyperextension cervical injuries

Age/sex	Circumstance	Blood alcohol level (mg/ml)	Location of vertebral injury	Past history	Co-existent pathology
70/M	Fall from bicycle riding	2.2	C4-5	Diabetes mellitus	Renal changes
72/M	Fall of 3 m height into small river	0.0	C4	Prostate cancer	Adenocarcinoma
67/M	Slip of 0.2 m height at front door	2.8	C4-5	Hypertension	Cardiomegaly
63/M	Fall from bicycle riding	1.3	C4-5, C5-6	Unknown	–
51/F	Slippage on flat road	0.0	C4-5	Schizophrenia	–
81/F	Fall from bicycle riding	0.0	C6-7	Hypertension	Atherosclerosis
51/M	Fall of 0.8 m height at road side	1.8	C4-5	Hepatitis	Chronic hepatitis
78/M	Fall of 2 m height into irrigation canal	0.9	C2-3	Gait disturbance	–
70/M	Fall from bicycle riding	1.9	C4-5, C6-7	–	–
76/M	Slip on slope of river bank	0.9	C5-6	Heart failure	Cardiomegaly (540 g), fibrosis in myocardium
52/M	Fall of 1 m height into irrigation canal	1.9	C4-5	–	–
53/M	Fall of 1 m height into small river	1.4	C4-5, C5-6	–	–
52/M	Slip on slope of field bank	1.2	C5-6, C6-7	–	–
70/M	Slippage on slope of mountain	0.0	C3	–	Atherosclerosis

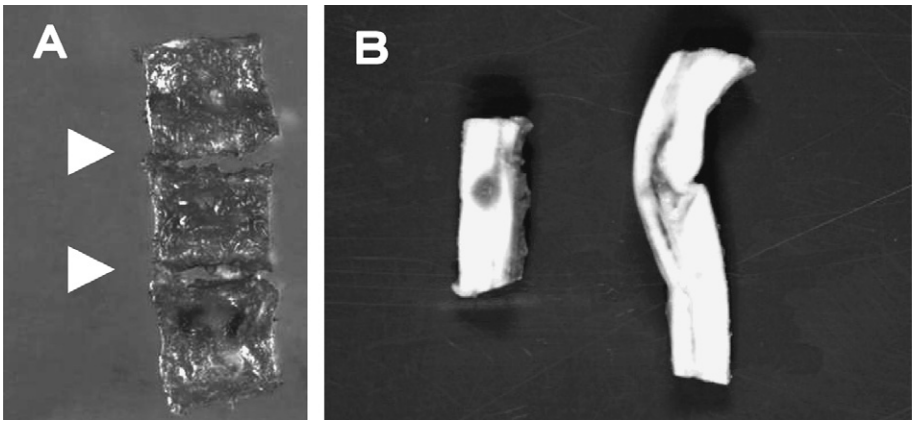

Fig. 1. Vertically sectioned cervical column to show disrupted discs (A) and longitudinal slices of the injured cords (B). In (A), double disruptions at the inter-vertebral disk spaces of C4–C5 and C5–C6 are observed simultaneously; arrows indicate the disruption sites. In (B), two typical cases of hemorrhage that occurred centrally in the damaged cords are demonstrated.

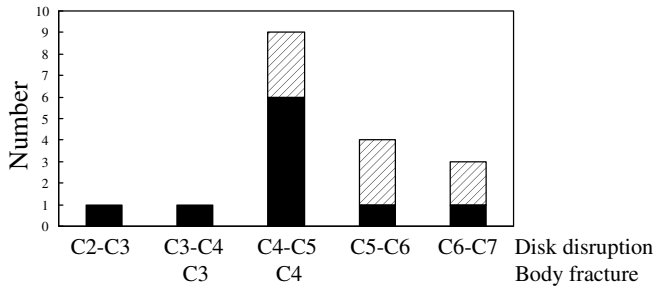

Fig. 2. The number and site of the disc disruptions and the vertebral body fractures of the cervical spine. Filled and slashed bars indicate single and double anterior disruptions, respectively, in the spinal column.

occurred preferentially in the white matter column of the ten damaged cords. Neuronal central chromatolysis, including mild dissolution of Nissle's granules, cytoplasmic swelling and nuclear vacuolar degradation, was also evident to some extent in eight cases (Fig. 3). However, the lesions exhibited varying degrees of neuronal degenerative features. No obvious changes were detected in three cases.

3.3. Death scene investigation

The circumstances of the fatal hyperextension injuries are summarized in Table 1. The elderly individuals (12 males and 2 females) displayed a mean age of 64.7 ± 10.9 years old at the time of injury. All of these individuals were found dead at the place where the accident occurred; moreover, none of these victims received emergency transportation, indicating that they likely died shortly after the accidental event. The subjects had neither diseases that cause sudden deaths or ankylosis. Each subject was conclusively supposed to sustain a live fall, not a secondary trauma in postmortem.

Four injuries resulted from falls during bicycling, six injuries were attributable to falls from a relatively low height, below approximately 2 m, such as with a small river

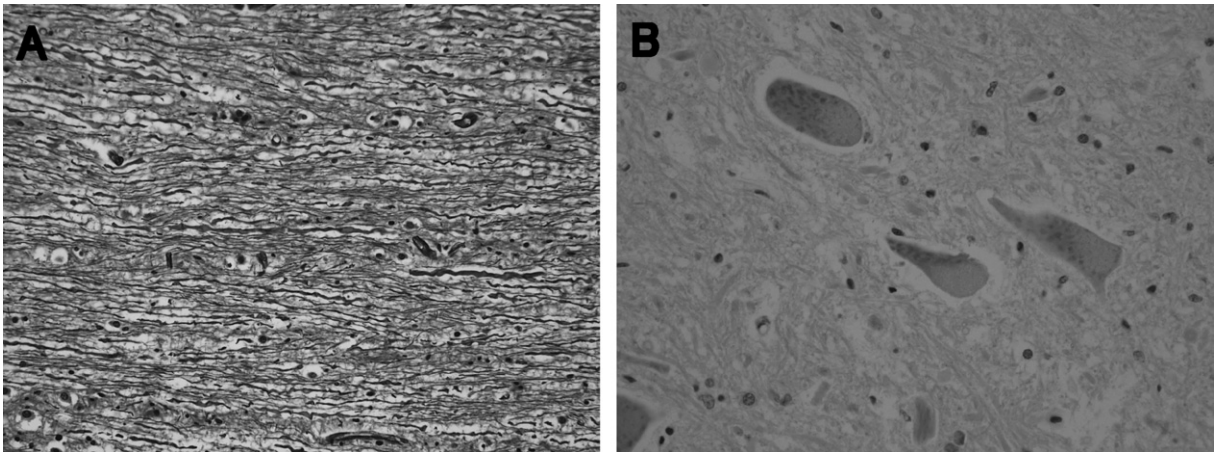

Fig. 3. Microscopy of the injured cord reveals axon degeneration and mild neuronal chromatolysis as well as (A), white matter with Bodian staining (×80) and (B), gray matter with hematoxylin/eosin staining (×100).

or a stair step, and the remaining four injuries were due to slipping on a slope of a road or a bank.

The high level of alcohol ($\geqslant$0.9 mg/ml of blood) detected in ten of the 14 cases is noteworthy. In all the aforementioned cases, the mode of death was ruled an accident; no death was ruled a suicide.

4. Discussion

In the current investigation, cervical spine injuries, which led to acute death, occurred consequent to a fall from a bicycle, a fall from a relatively low height, or slippage on a slope. Abrasions and lacerations on the face or the forehead were typical indicators of a fall or a blow. Backward motion of the head, which was partially accompanied by a compressive downward motion, likely contributed the major force.[1,7] Elevated blood alcohol levels were detected in 10 cases. Defensive posturing in order to circumvent impact of the face was inhibited due to the deleterious effects of alcohol on psychomotor skills and situational hazards.[13] The elderly males who had consumed alcohol may have been at high risk of spinal injury.

The cervical injuries potentially occur during postmortem. However, we thought that each primary cause of death in the present study was generated by the cervical injuries from the following reasons; no other severe injuries, the presence of vital reactions including bleeding in the prevertebral fascia and the spinal cords, the absence of ischemic changes in the heart, and no diseases that cause sudden death. An extensive search by Bohlman[14] demonstrated a mortality rate of nearly 20% following cervical spine injury.

Individuals who fall onto the face usually suffer 'central cord syndrome', which is characterized by disproportionate motor impairment in the upper rather than the lower extremities, bladder dysfunction, and variable degrees of sensory loss.[5,9] Most previous clinical studies regarding cervical spine injury dealt with survival subjects. Extrusion of the nucleus pulposus of the disk into the anterior canal cavity, as well as anterior subluxation, has been documented on roentgenogram and magnetic resonance imaging.[2,9,15] Several reports describe fatal cases involving hospitalization for several days were examined pathologically.[7–10] In contrast, all the victims of violent hyperextension exhibited complete anterior separation due to either a disruption at the inter-vertebral disk space or a transverse fracture of the vertebral body. Therefore, the findings in the present victims, who were found dead at the scene, appear to be somewhat distinct from those in clinical patients.

The mechanism of cord injury following cervical extension caused by facial impact is thought to be distinct from that of the whiplash injury observed in vehicular collisions, in which both flexion and extension forces are involved.[2,11] During separation of the anterior portion of the spinal column due to the extreme tensile force, the forward impingement of the ligamentum flavum, which is generated by the posterior compressive force, intrudes into the cord in the canal.[1,5,7] Consequently, the cord is damaged by stretching and squeezing at the bent canal.

The bony column injuries frequently occur at the lower level below the C4 vertebra. The extent of functional loss in cord injuries depends on the injured level of the spine. Cervical spine injuries above the C4 vertebra may be fatal as control of the diaphragm and intercostal muscles, which are necessary for respiration, is lost. Panjabi et al.[16] demonstrated that the mechanical force of cervical hyperextension affects lower cervical vertebrae below the inter-vertebral space between C4 and C5, and that the area between C5 and C6 is the most potentially damaged based on an experiment employing a skeletal model. Clinical investigations conducted by McMillian et al.[8] also revealed that the inter-vertebral space between C5 and C6 is prone to cervical injury. We think that the present results are consistent with these observations in principle; that is, the inter-vertebral space between C4 and C5 was the most frequently affected site in the column. In addition, double disruptions were evident at the inter-vertebral disc spaces (4/14, 29%). We also think that this multiple dislocation type, despite the scarcity of reports in the literature,[5] is not rare. In contrast, the actual mortality of the present cervical injuries was not clear. Axonal damage should extend beyond the C4 level due to the maximum degree of bending even at the lower cervical vertebrae, which might induce acute death.

Quencer et al.[9] demonstrated that axonal fragmentation predominantly occurs in the white matter column. Our result was consistent with their observation; however, the extent varied among the cases. In two instances, edema and macrophage invasion were evident, which suggested that the victims had been alive for several hours at the scene. The variability in terms of histopathology is conceivably attributable to the time elapsing between the accident and death.

In conclusion, the victims in this study exhibited common features, which resulted from a single impact of the face or the forehead owing to a falling or slipping from a low height; moreover, a number of elderly males characterized by elevated blood alcohol levels experienced accidental acute deaths. Although rare, this type of cervical injury, which is potentially overlooked during external postmortem examination, should be investigated by autopsy, which includes postmortem imaging.

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